ENERGY REQUIREMENTS AND SOIL DISRUPTION OF SUBSOILING

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Abstract

An experiment was conducted to determine the optimum moisture content at which to subsoil based on tillage forces and on soil disruption. Two different shanks, a straight shank and a "minimum-tillage" shank, were tested in a Coastal Plains soil (Norfolk sandy loam) in the soil bins of the National Soil Dynamics Laboratory in Auburn, AL. A three-dimensional dynamometer was used to measure tillage forces and a laser profilometer was used to measure soil disruption. Tillage forces and soil disruption from the driest moisture content were found to be greater than from all other moisture contents tested. The "minimum-tillage" shank was found to require more energy and disrupt the soil to a lesser degree than the straight shank.

Introduction

Subsoiling is commonly used to ameliorate compaction in Southeastern U.S. agriculture. A hardpan that impedes root growth is found at depths of 20-30 cm in many of these soils. Subsoiling is usually performed below these compacted soil layers to disrupt the soil profile. However, energy requirements can be substantial for this tillage operation. Also, it is hypothesized that tillage at an inappropriate time of the year when soil moisture is excessive would reduce the overall effectiveness of the practice. This study was conducted to:

1. Determine the force required to subsoil a Coastal Plain soil at several levels of soil moisture
2. Determine soil disruption caused by subsoiling at each moisture level
3. Evaluate the differences in draft and disruption caused by a straight subsoiler and a subsoiler designed for "minimum-tillage"

Materials and Methods

A Norfolk sandy loam soil (*fine loamy, kaolinitic, thermic Kandiudults*) located in the soil bins at the USDA-ARS National Soil Dynamics Laboratory in Auburn, AL was used for the experiment. A hardpan condition was formed in this soil to simulate a compacted condition that is commonly found in the Southeast. The shanks used for the experiment were manufactured by Deere & Co. (Fig. 1). The straight shank is 31.8 mm (1.25 in) thick with a 127 mm (5 in) LASERRIP™ Ripper Point and is currently used on the John Deere 955 Row Crop Ripper. The minimum tillage shank is 19 mm (3/4 in) thick with a 178 mm (7 in) Min-till point and is used on the John Deere 2100 Minimum-till Ripper.

A three-dimensional dynamometer was used to sense draft, vertical force, speed, and depth of operation at a speed of 0.45 m/s (1 mi/hr). The depth of operation of 33 cm (13 in) was kept constant for all tests. Daily measurements of soil moisture using a time-domain reflectrometry (TDR) probe were made to ensure that the targeted soil moisture level was achieved and that the next set of tests could be conducted. Four soil moisture levels were used to evaluate differences in subsoiler performance. Bulk density values were taken at depths of 5-10 cm (2-4 in), 20-25 cm (8-10 in), and 30-35 cm (12-14 in).

After each set of tillage experiments was conducted, a laser profilometer was used to determine the volume of soil disturbed by the tillage event. The above surface area, or the spoil area, provided a measure of the amount of soil that was displaced upward above the original soil surface by the tillage process. The disturbed soil was then manually excavated from the subsoiled or trenched zone for approximately 1 m (39.4 in) along the path of plowing to allow several independent profilometer measurements of the area of the subsoiled or trenched zone. Care was taken to remove only soil loosened by tillage.

A randomized complete block experiment was conducted that included four replications. An ANOVA was constructed using a probability level of 0.10 to test the null hypothesis that no differences existed between the soil moisture levels or between shanks.

Results and Discussion

The volumetric moisture content of the Norfolk sandy loam soil as determined by TDR was 16.3% for the wet condition, 13.3% for the moist condition, 8.3% for the dry condition, and 5.8% for the very dry condition. Bulk density values obtained showed the approximate location of the hardpan that was installed. In the Norfolk sandy loam soil, the surface bulk density from a depth of 5-10 cm (2-4 in) was found to be 1.58 Mg/m^3 while the soil within the hardpan at a depth of 20-25 cm (8-10 in) had a bulk density of 1.93 Mg/m^3 and the soil below the hardpan at a depth of 30-35 cm (12-14 in) had a density of 1.80 Mg/m^3.

Draft force measurements showed a statistically significant effect of soil moisture when averaged across shank type. Draft force from the very dry soil condition was found to differ from all other moisture treatments; 8794 N vs. 6374 N ($P \leq 0.003$) for the dry soil condition, 8794 N vs. 6810 N ($P \leq 0.009$) for the moist soil condition, and 8794 N vs. 5707 N ($P \leq 0.004$) for the wet soil condition (Table 1). Draft measurements except that from the very dry soil condition were not found to be statistically different from each other.

Draft force measurements were also found to differ based on the type of shank that was used ($P \leq 0.001$: Table 1). The straight shank on average was found to only require 5916 N of draft force where the "minimum tillage" shank required 7868 N of draft force. Only in the wet soil moisture treatment was the "minimum-tillage" shank not significantly different in requirement for draft force (5524 N vs. 5885 N). In all other moisture conditions, the draft force from the "minimum-tillage" shank exceeded the draft force of the straight shank.

Decreased soil moisture was found to greatly contribute to increased soil disruption aboveground (Table 1). The very dry soil moisture condition was found to have the greatest spoil area with a value of 409 cm^2 as compared to all other treatments. The minimum tillage shank (313.7 cm^2) was also found to have a smaller spoil area than the straight shank (361.2 cm^2).

Decreased soil moisture was also responsible for enlargement of the trenched area. This value was greater for the very dry soil moisture condition (916 cm^2) as compared to all other moisture conditions (Table 1). No statistical differences were observed between the two shanks tested.

Conclusions

1. Tillage forces obtained from the driest soil moisture treatment were found to be statistically greater than tillage forces obtained at all other soil moisture levels.
2. Measured values of soil disruption showed that the driest soil moisture treatment had significantly increased amounts of spoil and trench area as compared to all other soil moisture levels.
3. Increased draft forces were measured for the "minimum tillage" shank as opposed to the straight shank. However, the "minimum tillage" shank had reduced aboveground soil disruption (spoil) as compared to the straight shank.

Disclaimer

The use of trade names or company names does not imply endorsement by USDA-ARS.

Table 1. Tillage force and soil disruption for shanks operating at various moisture contents. Letters indicate statistical difference at the 0.10 level.

SHANK TYPE	SOIL MOISTURE %	DRAFT N	SPOIL AREA cm^2	TRENCH AREA cm^2
Straight shank	5.8 (very dry)	7086 abc	438 a	907 a
Straight shank	8.3 (dry)	5289 c	376 b	807 ab
Straight shank	13.3 (moist)	5400 c	358 bc	728 b
Straight shank	16.3 (wet)	5885 bc	273 de	741 b
Minimum tillage shank	5.8 (very dry)	11,067 a	380 b	926 a
Minimum tillage shank	8.3 (dry)	7459 ab	331 bc	737 b
Minimum tillage shank	13.3 (moist)	8215 a	313 cd	683 b
Minimum tillage shank	16.3 (wet)	5529 c	231 e	695 b

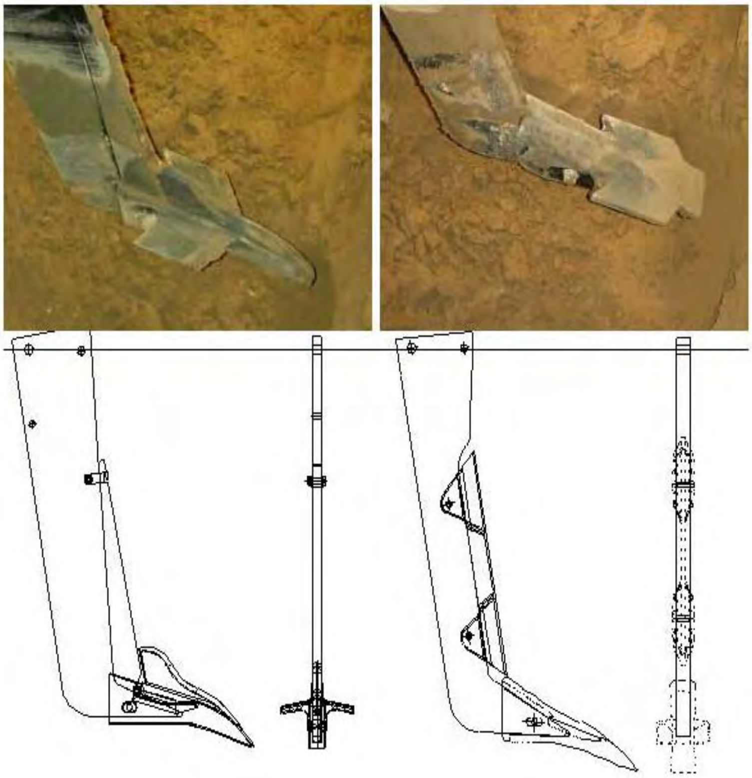

Figure 1. “Minimum-tillage” shank (left) and straight shank (right) used for experiment.